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NOTES ON SOME IGNEOUS ROCKS AT OGUNQUIT, MAINE, AND PIGEON COVE, MASS.

BY FRANK J. KEELEY.

It would probably be difficult to find a more remarkable display of igneous rocks than that along the coast of Maine south of Ogunquit. Here for a couple of miles the shale, dipping nearly vertically, is penetrated by almost innumerable dikes, varying from a few inches to over fifty feet in thickness and showing great variety in color and texture.

The shale itself, as the result of these numerous intrusions, has been metamorphosed and indurated until it is frequently as hard as the igneous dikes. Fresh fractures are usually gray with faint indications of differently constituted lamina, but on the weathered surfaces the various layers assume different colors, often producing a decidedly striped appearance resembling banded jasper, becoming particularly noticeable in the rounded pebbles occasionally lining the shore. Numerous ramifying veins of white and yellow quartz further characterize the shales, and the extremely rugged character of the coast line, with several coves and an overhanging cliff exceeding fifty feet in height, together with the almost unlimited variation in color due to weathering of the shale and its igneous intrusives, has resulted in this section becoming a favorite haunt of artists. From early times it has likewise attracted the attention of geologists, and in the first geological survey of Maine, published in 1838, Charles T. Jackson gives considerable space to the description of the features of this district and calls attention to the manner in which some of the dikes intersect each other, as indicating that the igneous intrusions can be referred to at least three periods.

During the past summer, with the view of becoming better acquainted with the petrographical character of these rocks, I collected a number of specimens, from which I have since prepared sections and studied them microscopically. The locality receiving particular attention was a small cove on Israel's Head, between the mouth of the Ogunquit River and Lobster Point. Here a patch of sand beach, used by the guests of the Ontio and Lookout Hotels as a bathing place, is surrounded by the usual shales of the region,

penetrated by several dikes and intrusions of igneous rocks. A series of these rocks was collected and this particular place selected for the purpose, not only because the intrusions seemed to include the principal types of igneous rocks, but also for the reason that they are located where they can be readily identified from the description by anyone interested.

Commencing with the rocky point which extends out to low-water mark on the north of the bathing beach, this is penetrated by a dike about twelve feet thick of diabase porphyrite with phenocrysts of plagioclase too much zoizitised for specific identification, in a matrix of diabasic texture, composed of augite, biotite, plagioclase, and chlorite, the latter apparently altered pyroxene; also as accessory constituents, titanite, apatite, and secondary calcite. Dr. F. Bascom, who kindly looked over these sections with me, suggests that the reason much of the pyroxene is entirely fresh or in part altered to hornblende, while in other cases it is completely replaced by chlorite, is probably that there may have been two distinct varieties of pyroxene originally present, one more readily altered than the other. Near contact with the shale, this dike becomes basaltic in texture, a fine-grained mixture of feldspar, biotite, magnetite, and brown hornblende, the latter no doubt replacing primary pyroxene, with phenocrysts having the outlines of pyroxene, almost invariably completely altered to chlorite.

A short distance toward the south, in the rocky wall back of the beach, is a twelve-inch dike of diabase with a small branch dike forking from it. Except that it contains a few small vesicles filled with secondary calcite, this is a typical diabase, fine and uniformly grained. Beyond it is a dike of basalt, four to eight inches thick. At the contact it is glassy, with lath-shaped feldspars oriented parallel to the wall. The interior is more completely crystalline, with phenocrysts of pyroxene altered to chlorite and many small, rounded patches of calcite, apparently filling vesicles.

Further south is an irregular angular intrusion of trachyte. It consists almost exclusively of intermeshed rods of feldspar, apparently orthoclase somewhat kaolinized, with scattered patches of ferruginous material slightly translucent and dark red in color when sufficiently thin, also generally red by reflected light. This rock corresponds in texture to the dyke rocks which have received the name of bostonite, but in the absence of any microscopical evidence of the presence of anorthoclase, a chemical analysis would probably be necessary to determine whether it should be so classed.

Next comes another dike of diabase, characterized by the presence of considerable pyrite, which occurs in rounded aggregates, filling the interstices between crystals of augite and plagioclase. It also contains vesicular cavities averaging about a millimeter in diameter, filled with calcite and a little quartz, margined by acicular secondary hornblende.

Somewhat south of the beach is a large intrusion having an irregularly rhomboidal outline, consisting of trachyte porphyry with large orthoclase phenocrysts in a felsitic matrix containing some hornblende and a little quartz.

Four sections were made from specimens of the shale associated with dikes mentioned, one broadly striped, another showing finer laminations, and the remaining two of rather uniform texture. All are highly silicious, including quartz grains up to a half millimeter in diameter scattered among finer grains of quartz and some secondary minerals, chiefly micas, sometimes biotite, and in one sample, a bright green mica. The extent of metamorphism is indicated by apparent metasomatic penetration of the secondary minerals into some of the primary quartz grains. Striping, when present, is due to the concentration of such secondary minerals in layers, which in the original sediment were probably less purely silicious than the rest.

Beyond a gully south of Lobster Point is a very noticeable dike about five feet in diameter, transected at an acute angle by another of same size. The first may be classed as a diabase porphyrite and contains vesicles about a millimeter in diameter such as characterize so many of the dikes here, but in this case there is about as much quartz as calcite in the cavities, while generally the filling is entirely of calcite. This rock also contains much pyrite in the form of isolated grains in the interior of the dike, but in clouds of minute particles several millimeters across, in the basaltic textured rock near the contact. The other dike is an olivine diabase, notable for numerous large idiomorphic phenocrysts of olivine now completely altered to serpentine of unusually high double refraction, apparently consisting, in part at least, of chrysotile, showing development along irregular cracks, so characteristic of the alteration process in olivine.

Possibly a mile further south, beyond Perkin's Cove, there is exposed on the shore an extensive intrusion of diabase, under which there is a water-worn cave between tide levels, locally known as the Devil's Kitchen. This rock is a rather coarse-grained diabase with some primary biotite, in which the augite is perfectly fresh, but another ferro-magnesian constituent originally present has been

completely altered to a brown serpentine-like material sometimes apparently mixed with felted masses of biotite and chlorite. This may have been an orthorhombic pyroxene, as slight traces of it remaining in the heart of a couple of the brown areas showed parallel extinction, and it has none of the characteristics of olivine. In addition to the usual magnetite, apatite is present as an accessory mineral, but not at all plentifully.

While the indurated shale is continuous along the sea coast for a couple of miles south of Ogunquit, granite outcrops at a number of places not far back from the shore, as at Pine Hill and further to the west at Mt. Agamenticus. It is hornblendic at the outcrops noticed, but I did not collect or further study any specimens. Some additional collections of dyke rocks were, however, made just north of Ogunquit on the road to Portland. Here, in widening the road, several outcrops have been cut away, leaving fresh exposures. One such is located on east side of road about one-eighth mile north of the car barn and shows three different igneous rocks penetrating or in contact with each other. Toward the south, there is first a gray, medium fine-grained diabase, then a compact black basalt. A section of the contact demonstrates that the basalt was a later flow than the diabase. Next to it comes a coarse diabase porphyrite with feldspar phenocrysts, sometimes exceeding an inch in length, and beyond this another fine-grained diabase, and then indurated shale similar to that described from the shore.

On the west side of the road, one-eighth mile further toward the north, is another good exposure of diabase porphyrite, in which the phenocrysts are developed to an extent that they appear to make up more than half the rock, in contact with basalt of later origin.

For comparison, I give the following brief description of igneous rocks at Pigeon Cove, Mass., where years ago I collected and studied specimens from the dikes along a similar short section of the shore. The end of Cape Ann consists of light gray hornblende granite, quarried extensively for commercial purposes. Its feldspar is almost exclusively microcline and the hornblende is generally accompanied by biotite. This granite is penetrated by many igneous dikes, although these are not so numerous or varied in character as those at Ogunquit.

Near the extreme point of the cape, known as Andrew's Point, below an unfinished square stone tower, is a dike of solvsbergite, a uniformly crystalline mixture of plagioclase with hornblende showing pleochroism from olive to indigo-blue, much finer grained in

an offshoot which extends into a parallel crack in the granite. A block of granite which has been picked up by the molten dike rock is exposed in the interior of the latter.

East of this is an extensive intrusion of quartz porphyry, so classed from the general characteristics of the whole mass, rather than from the microscopical examination of individual sections, some of which would otherwise rank as fine-grained granites, while others show a few phenocrysts and patches of micro-pegmatite. Within this intrusion are segregations containing crystals of hornblende several inches long and large masses of blue quartz. It has been injected with diorite, but as it does not split in straight lines like the granite, no regular dike is exposed. The diorite has forced its way irregularly among the fragments of the older rock, some of which are included in it. The diorite consists of a fine-grained mixture of hornblende, biotite, and triclinic feldspar, with a few phenocrysts of zoisitized plagioclase and occasionally a small one of light colored pyroxene. It is intersected by numerous small white veins, no doubt of secondary origin, and consisting in one section examined of feldspar, both orthoclase and plagioclase, and light colored pyroxene.

To the south, the dike of solvsbergite, which crosses the point, again appears, and further on a sharply defined dike of quartz porphyry several feet thick. Still further south are three small dikes of diorite, differing from that at the point in several minor respects. There is but little biotite, and the hornblende is of a bluish-green color. No veins were noted, and the smallest dike, which is but a few inches thick, is very fine-grained and free from phenocrysts. They are probably all derived from the same source.

Beyond them comes another series of dikes, all no doubt of similar origin. They are, respectively, two to three inches, twenty-eight inches, sixteen inches, and eighteen feet in thickness, the latter just below the Ocean View Hotel, while further on is still another nearly as large. The larger dikes are typical fully crystallized diabases, coarser or finer grained according to size of dike, with unaltered constituents and basaltic texture near the contacts. The two- to three-inch dike is basaltic throughout. It passes close to a swimming pool blasted out of the rocks, and is visible over the sloping shore for a couple of hundred feet, occupying a crack in the granite as straight and sharply defined as if cut with a knife.

The sixteen-inch dike is admirably adapted for illustrating the effect of quick or slow cooling on an igneous rock, as it has an offshoot or branch, three-eighths to two inches thick, extending into the

granite. Where three-eighths to one-half inch thick, chips of the rock are procurable which permit of sections being made showing the granite penetrated by the small dike. Here the matrix is an almost opaque glass with plagioclase rods and phenocrysts of augite. When it becomes three-fourths inch thick, a slight tendency toward crystallization of the matrix is noticeable in the centre, and so on until the middle of the main dike is reached, where but little trace of the basaltic texture remains and the rock is a characteristic diabase. A similar series of sections can of course be made by starting from the contact in one of the larger dikes, but the transition from basalt to diabase is much more sudden.

Two other rocks occurring nearby, but not appearing on the shore line just considered, are worthy of mention. One is a highly porphyritic andesite with phenocrysts sometimes two inches long, indicated by their extinction angles to be oligoclase, in a matrix consisting of uralite, biotite, and plagioclase. This rock is not well exposed at Pigeon Cove. I have noted an outcrop in a door yard near centre of village and another in a hollow west of what is known as Sunset Rock, but across Sandy Bay it appears as a sharply defined dike in the granite, on the shore between Rockport and Straitsmouth. As the granite here seems capable of cleaving in a straight line for an indefinite distance and the three exposures are approximately in line, although widely separated, they may all pertain to the same dike. The other rock referred to occurs in a cut leading from the shore to the Rockport Quarry, near the archway under main road. It is a light brown crystalline rock which proved to consist entirely of micro-pegmatite, the best example I have seen of this intergrowth of quartz and microcline.